7

An Introduction to Power

Basic Concepts

- Identify the difference between work and power.
- Define power.
- Identify the basic power systems.
- List the basic elements of all power systems.
- Define horsepower (hp).

Intermediate Concepts

- Recognize the various power components in electrical circuits and fluid circuits.
- Summarize the advantages and disadvantages of various forms of power.

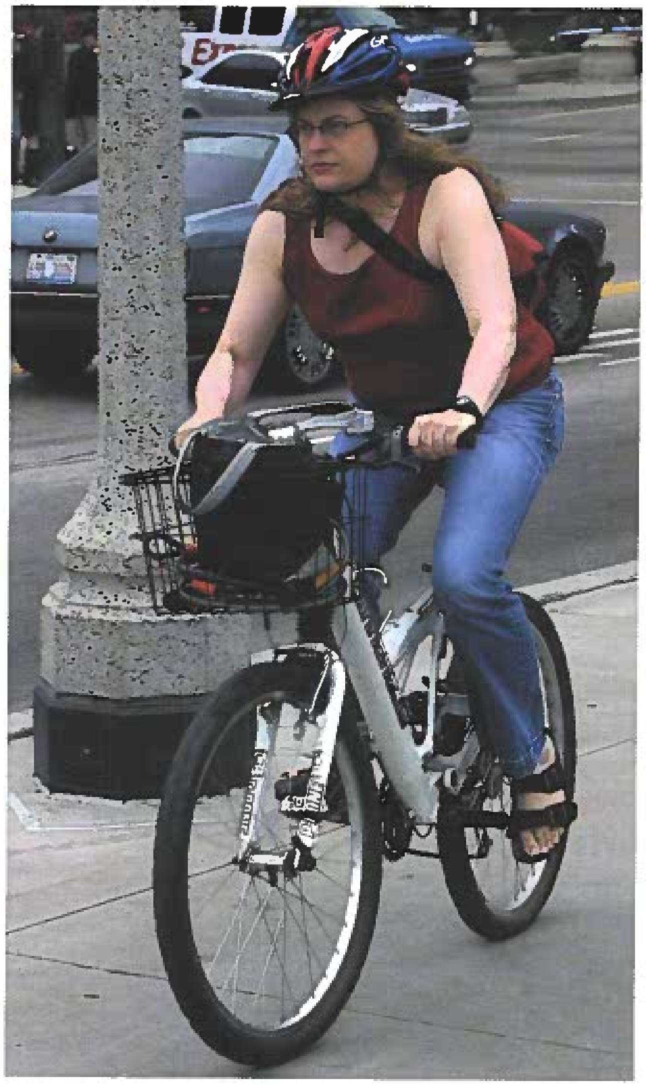
Advanced Concepts

- Describe various forms of power for specific applications.
- Diagram the basic power components in an electrical circuit or a fluid circuit.
- Calculate the efficiency of power systems and conversion devices.
- Compute power and hp for various forms of power.

Power is needed in our technological society. It lights our cities, cooks our food, and washes our clothes. Power is also needed in our transportation systems. Without power in transportation, cars could not run, airplanes could not fly, and subways could not operate. Power is something that is easily taken for granted. We do not often think about where the power needed to perform specific tasks comes from. As you ride your bicycle, think about what makes it move:

- You supply the energy to turn the pedals.
- The energy you supply is then changed into a form of power.
- As the pedals turn, the chain and gears power the bicycle. See **Figure 7-1.**

Figure 7-1. Pedaling a bicycle converts human energy into mechanical power to drive the chain and gears, moving you and the bicycle forward.



Types of Power Systems

Work is the application of force that moves an object a certain distance. Power is the rate at which work is done. Sources of energy, such as wind, solar, and heat, are harnessed to perform useful work. When energy is harnessed, converted, transmitted, and controlled to perform useful work, we call this a *power system*. In the harnessing of energy sources, machines are used to convert energy into movement.

Electrical Systems

Electrical systems are power systems that use electrical energy to do work. The most common electrical power components include switches for controlling the flow of electricity, fuses or circuit breakers for protecting electrical circuitry, wires for transmitting electricity, and loads (such as lights, heaters, motors, or appliances) for utilizing electricity. Consider what your world would be like if electricity was not available. You would not have light to allow you to easily function when it is dark outside. To get hot water for a shower, you would need to build a fire to heat the water. Using a toaster to make toast for breakfast would not be an option. Electrical systems affect each of us daily!

Consider, also, how electricity is important to our technological world. Manufacturing plants need electricity to run machines. Without electricity, products like stereos and bicycles could not be produced. The communication systems around us could not operate without electricity. The television, telephone, and radio would be useless pieces of equipment without electricity. Our system of transportation would not be as efficient and safe as it is today without an electrical system. An electrical system is needed for traffic signals and for the air bag safety system in automobiles. Electricity propels several modes of public transportation, as well. It is needed in most everything we use today. Electrical systems are discussed further in Chapter 8.

Work: The application of force that moves an object a certain distance.

Power system: A system in which energy is harnessed, converted, transmitted, and controlled to perform useful work.

Mechanical Systems

Mechanical systems are power systems that use mechanical energy to do work. This is energy created by motion. *Machines* are devices used to manage mechanical power. Six simple machines are used to control and change mechanical power: the lever, the pulley, the wheel and axle, the

Technology Link

Communication: Radios and Satellites

Several kinds of communication technology rely on energy and power to work properly. Radios and satellites transmit signals by altering electromagnetic waves with frequencies below those of light. These waves travel through the atmosphere and space.

In the early 1900s, it was discovered that messages could be combined with waves of electromagnetic energy that radiate through space at the speed of light. The discovery of radio waves allowed people to instantaneously communicate over great distances. Within a few years, millions of people all over the world were tuning in to radio broadcasts for news and entertainment.

Satellites use super high frequency (SHF) electromagnetic waves, or microwaves, to transmit information across great distances. These waves travel directly from the satellite to its primary coverage area. Satellites can provide the signals for radio detecting and ranging (radar) systems, global positioning systems (GPSs), cellular telephones, and television.

The communication devices we use on a daily basis depend on the technology of electromagnetic energy. Without energy technology, we would not be able to send and receive information nearly as easily or quickly. Communication technologies are continuously evolving and improving, and in the coming years, we may see new technologies that allow us to communicate even better.

inclined plane, the wedge, and the screw. See **Figure 7-2.** These simple machines are explained in more detail in Chapter 9.

Machines used to produce work create mechanical energy. A machine or combination of machines can change the size, direction, and speed of force. Machines can also change the type of motion produced.

These systems are often used to harness energy from the wind, the force of water behind a dam, and high-pressure steam. When potential energy is harnessed and converted into mechanical power, it can be used to do work. Sometimes, mechanical power is put directly to work without any changes. For example, the blade on a lawn mower is connected directly to the power source—the crankshaft of a small gas engine. Most often, however, a change in the mechanical power is necessary before putting it to work. Mechanical power always has a direction of motion. This may be linear (straight and in one direction), reciprocating (back and forth), or rotational (spinning).

Fluid Systems

Fluid systems perform work using the energy created by liquids and gases. Fluid power can accomplish the movement of very heavy objects. Entire buildings and houses have been moved by the use of fluid power. This is why fluid power is referred to as the "muscles of industry." Examples of fluid power components include valves, hoses, air compressors or hydraulic pumps, cylinders, and motors.

Electrical system: A power system that uses electrical energy to do work.

Mechanical system: A power system that uses mechanical energy to do work.

Machine: A device used to manage mechanical power.

Fluid system: A power system that uses the energy created by liquids and gases to do work.

Pneumatic: A type of fluid power system that uses a gas, such as air, to transmit and control power.

Hydraulic: A type of fluid power system that uses a liquid, such as oil, to transmit and control power.

GREEN TECH
Certain types of hydraulic fluids are made from more natural substances, such as vegetable oil. Fluids like these are considered biodegradable and better for the environment.

Figure 7-2. These six simple machines control all mechanical energy. Complex machines are combinations of two or more simple machines.

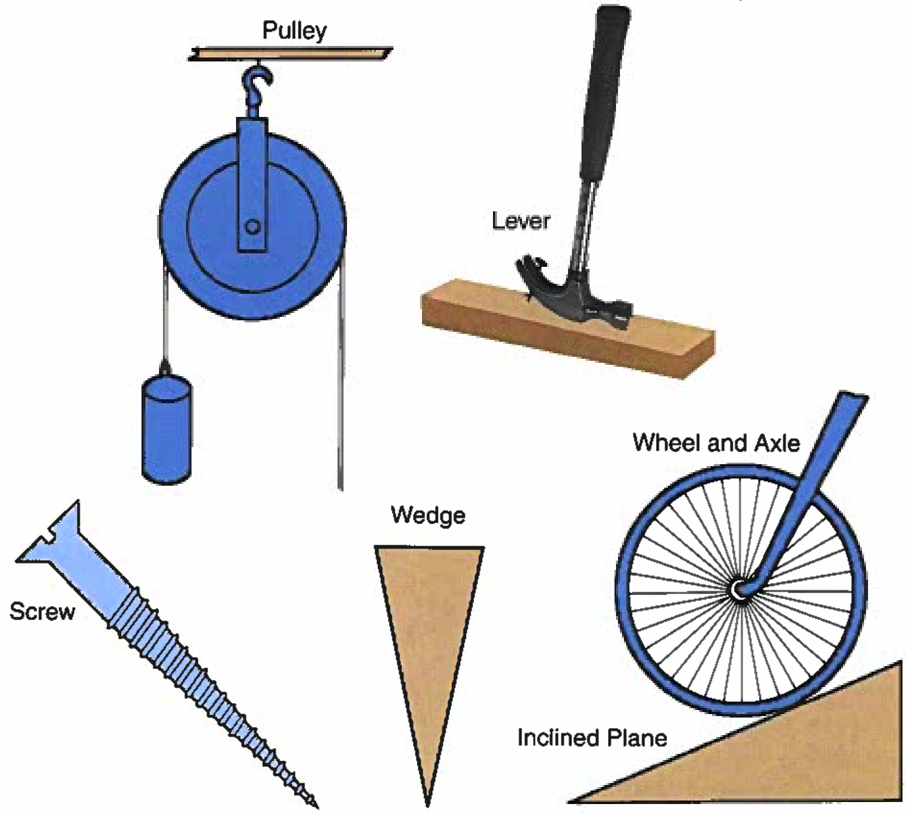


Figure 7-3. Many machines used in construction, such as this end loader, use hydraulics to transmit power and control machine functions.

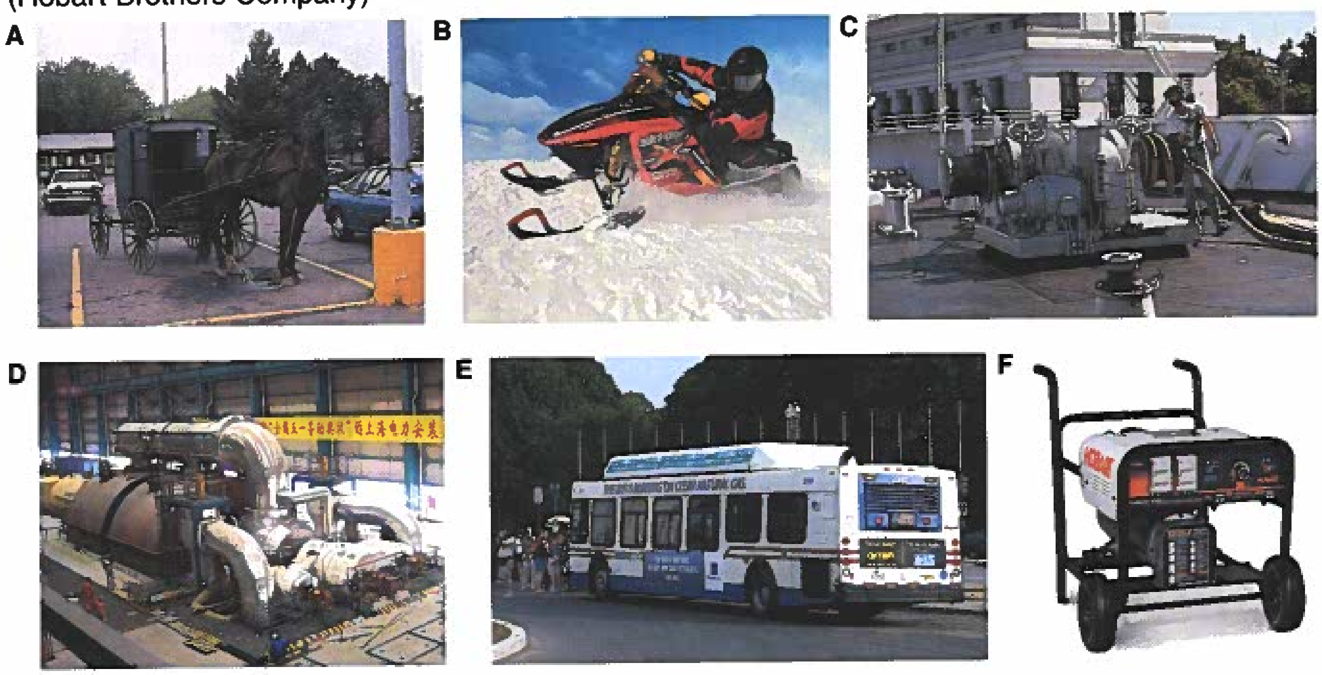
There are two types of fluid power systems: pneumatic and hydraulic. ***Pneumatic*** systems use a gas, such as air, to transmit and control power. ***Hydraulic*** systems use a liquid, such as oil, to transmit and control power. See **Figure 7-3.** A hydraulic system controls and operates the landing gear on airplanes. The process of forging parts in industry is accomplished by the use of pneumatics or hydraulics.

Fluid power has many advantages over the other forms of power. Mechanical power is often slow and awkward. Electrical power is often expensive and complex and is often converted back to mechanical power to do useful work. Fluid power systems are easily operated and controlled, durable, and accurate in their control. Chapter 10 explains the uses and principles of fluid power in more detail.

Characteristics of Power Systems

Power systems come in various sizes and perform a wide variety of tasks. See **Figure 7-4.** An automobile is a power system because the fuel is converted into power. A motor is a power system because electricity is

Figure 7-4. Examples of power systems. A—An animal's muscle energy can be used to power a vehicle or operate a machine. (Howard Bud Smith) B—Chemical energy from petroleum is converted to mechanical energy to power this snowmobile. (Bombardier, Inc.) C—Electrical energy is changed to mechanical power to operate this large shipboard winch. (Howard Bud Smith) D—Heat energy (steam) is converted to mechanical energy in this turbine to generate electric power. (Siemens) E—Chemical energy, in the form of natural gas, is converted to mechanical power to fuel this city bus. F—A welding generator converts chemical energy into electric power. (Hobart Brothers Company)



converted into power. An electric power plant is another good example of a large power system. See **Figure 7-5.** Power can be produced in three forms: electrical, mechanical, or fluid. In any of these three forms, power is comprised of two basic, measurable characteristics: effort and rate.

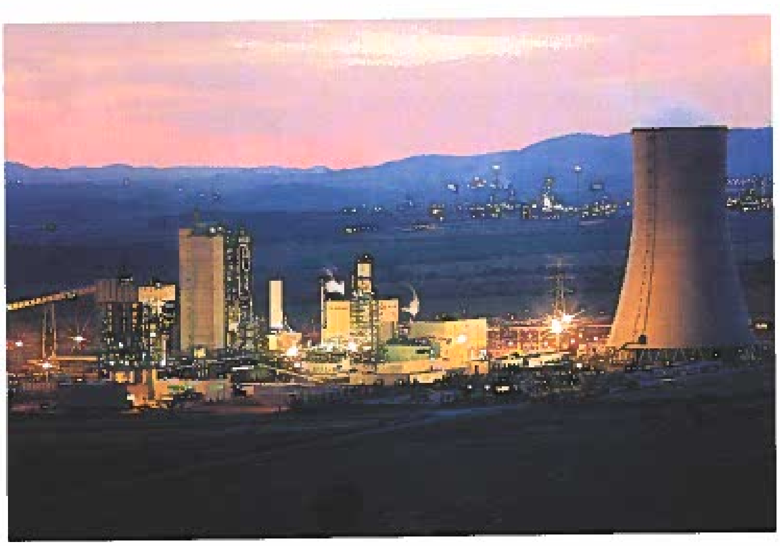


Figure 7-5. A large electrical generating plant in Spain. Coal is pulverized before being burned, providing maximum energy recovery, while decreasing pollution. (Siemens)

Effort: The force behind movement in a power system.

Force: Effort, in mechanical power.

Torque: Effort, in rotary mechanical power.

Foot-pound (ft.-lb.): The amount of force necessary to move a 1-lb. load a distance of 1′.

Pressure: Effort, in fluid power.

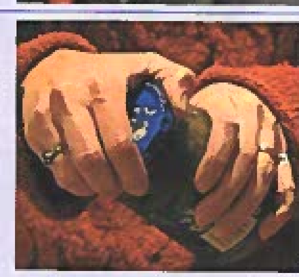
Pounds per square inch (psi): A unit used to measure pressure.

Effort

Effort is the force behind movement in a power system. See **Figure 7-6.** In linear mechanical power, this effort is usually known as ***force*** and is usually measured in pounds. In rotary mechanical power, the term for effort is ***torque***. Torque is a twisting or turning force. It is typically measured in foot-pounds (ft.-lbs.). A ***foot-pound (ft.-lb.)*** is the amount of force necessary to move a 1-lb. load a distance of 1′. You can see and feel the effects of force in mechanical power. When lifting an object that weighs 50 lbs., you need to generate more than 50 lbs. of pulling force to overcome the weight of the object.

In fluid power, effort is referred to as ***pressure***. It is usually measured in ***pounds per square inch (psi)***. Imagine turning on a garden hose. Without pressure, water would not flow from the hose. Water from a drinking fountain that has too little pressure is difficult to drink because

Figure 7-6. Some examples of the units of measure for effort in power systems.

Electrical	*Potential difference (voltage)* — causes the displacement of electrons	
Fluid	*Pressure difference* — causes the displacement of a fluid (liquid or gas)	
Mechanical (Linear)	*Force* — causes the linear displacement (vertical or horizontal) of a mass	
Mechanical (Rotary)	*Torque* — causes rotary displacement of a mass	

the water barely flows above the nozzle. On the other hand, water from a drinking fountain that has too much pressure may spray or overshoot the water basin.

In electricity, the effort behind the movement of electrons is called ***voltage***. Voltage within a wire cannot be seen. Imagine a garden hose with marbles flowing out of it. The marbles represent the flow of electrons, and the pressure behind the marbles, pushing them through the hose, is the voltage. Just like a water fountain with too little pressure is not easy to drink from, an electrical circuit without adequate voltage does not work properly. A flashlight with old batteries that provides only dim light is a good example of inadequate voltage.

Voltage: In electricity, the effort behind the movement of electrons.

Rate: The characteristic of power that expresses a certain quantity per unit of time.

Ampere: In electrical power, the measurement for rate of flow.

Rate

Rate is the characteristic of power that expresses a certain quantity per unit of time. See **Figure 7-7.** Regardless of the unit of measure, all rate characteristics include both a quantity (gallons, electrons, revolutions, or distance) and a time element (seconds, minutes, or hours).

In electrical power, the measurement for rate of flow is the ***ampere***. As ampere flow increases, a greater amount of work can be accomplished. For instance, a lightbulb that draws 2 amperes produces more light than the same type of bulb that draws just 1 ampere when the same voltage is applied to both bulbs.

Figure 7-7. Some examples of the units of measure for rate in power systems.

Electrical	*Ampere rate* = $\frac{\text{Electrons displaced}}{\text{Time}}$	
Fluid	*Fluid rate* = $\frac{\text{Flow}}{\text{Time}}$	
Mechanical (Linear)	*Linear mechanical rate* = $\frac{\text{Mass displaced}}{\text{Time}}$	
Mechanical (Rotary)	*Rotary mechanical rate* = $\frac{\text{Revolutions}}{\text{Time}}$	

Revolutions per minute (rpm): A measurement of movement in a rotational mechanical system.

Gallons per minute (GPM): One of the most common measurements of rate of flow in a fluid system.

Energy source: A force that has the capacity to do work.

In mechanical power, the rate characteristic involves a type of movement per time. If the mechanical system is a rotational system, the movement is usually measured in ***revolutions per minute (rpm)***. The rate is often determined in a measure of distance per time, such as feet per second (fps) or feet per minute (fpm), if the mechanical system is linear (like a conveyor belt). Since cars can travel great distances, it is necessary to use a larger scale for measuring rate. Most people are familiar with the speedometer in a vehicle that measures in miles per hour (mph).

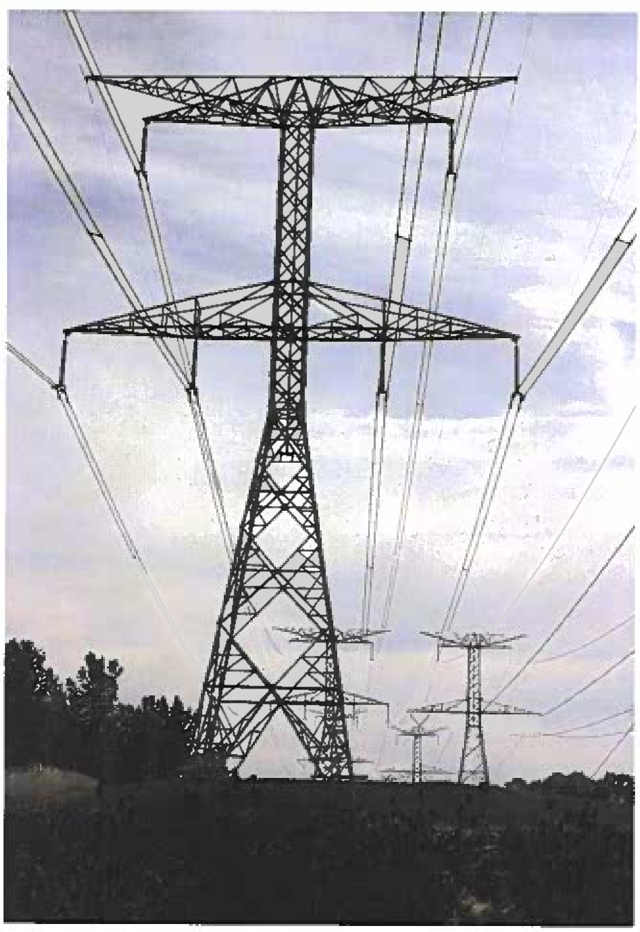
Water flowing from a garden hose is an example of flow in a fluid system. The water flows from the hose as a result of pressure. The rate at which the water is flowing can be measured in terms of volume per time. One of the most common measurements of rate of flow in a fluid system is ***gallons per minute (GPM)***.

Basic Elements of All Power Systems

The three basic power systems are electrical, mechanical, and fluid. No matter how big or small these power systems are, they each have basic elements, or functions, in common. From a lawn mower to a power plant, every power system incorporates these basic functions:

- An ***energy source*** is required for a power system to function. Fuel is often used as an energy source, but other sources, such as water or wind power, may also be used.
- A ***conversion method*** is necessary to convert energy so some type of work is produced. For example, falling water spins a turbine that operates an electrical generator to produce electricity.
- A ***transmission path*** is needed to move energy to the point where it is supposed to produce work. An example of a transmission path is the electrical power lines often seen strung across the landscape. See **Figure 7-8**. These paths provide a means of transporting energy from the point where it was generated to where it will produce work.
- A ***storage medium*** is necessary when power must be stored for use at a later point in time. A battery is a common type of power storage device. A spring is a mechanical power storage device.
- ***Protection devices*** shield components in power circuitry from excessive effort or rate of flow. For example, fuses protect an electrical circuit from too many amperes flowing through the circuit.
- ***Advantage-gaining devices*** modify the effort and rate characteristics of power in order to

Figure 7-8. Electrical power lines are the transmission paths for electrical energy from the generating station to the end users.



achieve a goal. A lever, for example, can multiply force to create additional leverage. Similarly, a step-up transformer can create a high voltage suitable for transmission over great distances. A step-down transformer reduces the voltage, while providing higher amperage suitable for household use. Advantage-gaining devices cannot produce more power than they utilize. They can only modify the effort and rate characteristics of the total amount of power provided.

- ***Control systems*** are needed to control the power within a system. The simplest type of control is an on-and-off motion control. More complex control systems include one-way motion control and variable motion control. The throttle on a lawn mower is a control system. See **Figure 7-9.**
- ***Measuring devices*** are required in power systems and provide a source of feedback to monitor how well the system is functioning. They include meters, indicators, and gauges.
- A ***load***, or output, is the final goal of the power system. It is the work done by the system. For example, a lawn mower's load is the cutting blade. Electrical loads include lighting, motors, heating elements, and appliances. Fluid power loads include cylinders for linear motion and motors for rotary motion.

Calculations of Power Systems

The power available in a system can be measured or calculated for each form of power—electricity, fluidics, or mechanical. The ability to measure power is important since it can tell us many things about how a power system is performing. For instance, measuring mechanical power can tell us if an engine is producing power to specification. Calculating the electrical power used in a circuit can help us estimate how much using a particular machine or appliance for a number of hours will cost.

Figure 7-9. Control systems may be one-way or variable. The throttle of this lawn mower (inset) is used to vary the amount of power from the source (engine) to the load (cutting blade).

Conversion method: A necessary process to convert energy so some type of work is produced.

Transmission path: A means of transporting energy from the point where it was generated to the point where it will produce work.

Storage medium: A device that is necessary when power must be stored for use at a later point in time.

Protection device: A device that shields components in power circuitry from excessive effort or excessive rate of flow.

Advantage-gaining device: A device that modifies the effort and rate characteristics of power in order to achieve a goal.

Control system: A system necessary to control the power within a system.

Measuring device: A device required in power systems that provides a source of feedback to monitor how well the system is functioning.

Career Connection

Power Line Repairers

Manufacturing

A power line is an example of a transmission path. Energy is transported through power lines over great distances before it can be made useful as work. Power lines distribute electricity across the country, from generators to buildings. Power line repairers are necessary to ensure the public has continued use of electricity.

The job of a power line repairer involves a great deal of physical work. Power line repairers must replace poles and wires. They must repair and then test the power lines in order to ensure safety and functionality.

Power line repairers must have knowledge of mechanical and electrical principles. They must be able to work the machines necessary to aid in their repair work. Power line repairers have to work within safety limits so as to not hurt themselves or anyone else in the area. To be a worker in this field, long-term on-the-job training is required. The yearly salary may range from $31,000 to $78,000.

Load: An output that is the final goal of the power system. It is the work done by the system.

Work

Work creates movement by using a form of energy. Calculate work using the following formula:

- work = distance × force (W = D × F)

Force times the distance through which the force acts equals work. Work is measured in ft.-lbs. for conventional U.S. measure.

Suppose a rider in a canoe weighs 120 lbs. How much work is being done, if the canoe is paddled 600′?

- W = D × F
- W = 600′ × 120 lbs.
- W = 72,000 ft.-lbs.

If 2000 lbs. have to be moved 30′, how much work has to be done?

- 2000 lbs. × 30′ = 60,000 ft.-lbs. of work

Power

Power is the amount of work performed over a period of time. It can be calculated by using the following generic formula:

- power = work/time (P = w/t)

When referring to mechanical power, the equation may be written as: P = F × D/t

In this equation, *F* stands for force and is usually measured in pounds. *D* stands for distance and is usually measured in feet. The following is an example of using the mechanical power formula:

If a crane operator is going to move a 1000-lb. barrel of nails up 40′ to a fourth story window in 30 seconds, how much power is developed?

- P = 40′ × 1000 lbs./30 seconds
- P = 40,000 ft.-lbs./30 seconds
- P = 1333 ft.-lbs. per second

In electrical power systems, power is measured in ***watts***. The quantity of effort in determining watts is known as voltage. Voltage is the force pushing the electrical current through the conductor. The rate factor is typically referred to as amperage. ***Amperage*** refers to the rate at which electrons or coulombs move through a conductor. The ***coulomb*** is a unit of electrical charge equal to the amount of electricity transported by 1 ampere in 1 second. As an example, assume that an electric heater operates at 220 volts and draws 10 amperes. How much electrical power is being utilized?

- effort × rate = power
- 220 volts × 10 amps = 2200 watts

This formula is known as ***Watt's law*** and will be discussed in greater detail in Chapter 8.

Efficiency

Efficiency is the relationship between input energy, or power, and output energy, or power. Measuring and calculating the efficiency of a power system is important to the process of improving efficiency. Efficiency is important to all forms of power devices, as well as energy and transportation devices. It is determined by using the following generic formula:

- output/input × 100 = percentage of efficiency

Use the efficiency formula to determine the efficiency of an electrical transformer designed to double the voltage fed into the transformer:

- input voltage = 120 V
- output voltage = 240 V
- input amperage = 20 A
- output amperage = 8.7 A

Both voltage and amperage are needed to measure wattage. Watt's law provides an equation (wattage = amperage × voltage) to measure electrical power in watts.

1. Use Watt's law to determine power in and power out.
   W = V × A
   120 V × 20 A = 2400 W (in)
   240 V × 8.7 A = 2088 W (out)
2. Use the efficiency formula to determine the efficiency of the transformer.
   output/input × 100 = percentage of efficiency
   2088 W/2400 W × 100 = 87% efficient

Calculate the efficiency of a gear set with the following characteristics:

- Drive gear: 20 ft.-lbs. torque at 100 rpm
- Driven gear: 9.7 ft.-lbs. torque at 200 rpm
  20 ft.-lbs. × 100 rpm = 2000 (in)
  9.7 ft.-lbs. × 200 rpm = 1940 (out)
  1940/2000 × 100 = 97% efficient

Calculating the efficiency of a power system is slightly more complicated than calculating the efficiency of an individual component, such as the transformer or gear, previously presented.

Watt: A measurement of power in electrical power systems.

Amperage: The rate at which electrons or coulombs move through a conductor.

Coulomb: A unit of electrical charge equal to the amount of electricity transported by 1 ampere in 1 second.

Watt's law: Power equals effort multiplied by rate.

GREEN TECH

Efficiency is an important calculation where power is concerned. Some energy will be lost during conversion, but some devices, such as wind generators, do not result in as much waste of resources.

Determine the total system efficiency of a wind generator. See **Figure 7-10.** Each component of the wind generator system is described below, with a corresponding efficiency.

- The blades of a wind generator convert about 55% of all air flowing through them into useful mechanical power.
- The generator converts about 90% of all the mechanical power into electricity.
- The inverter changes the electricity into a suitable voltage for household use. It is about 85% efficient.

To find the efficiency of the entire system once the efficiency for each component is known, multiply the efficiency of each component with the next component, until all have been factored into the equation. Note that the efficiencies are represented in decimal form.

- .55 × .90 × .85 × 100 = 42% total system efficiency

Horsepower (hp)

Horsepower (hp): The standard measuring unit of power equal to the energy needed to lift 33,000 lbs. 1′ in 1 minute.

Horsepower (hp) is one standard measuring unit of power. The energy needed to lift 33,000 lbs. 1′ in 1 minute equals 1 hp. Calculate hp by using the following formula:

- hp = work/(time in minutes × 33,000)

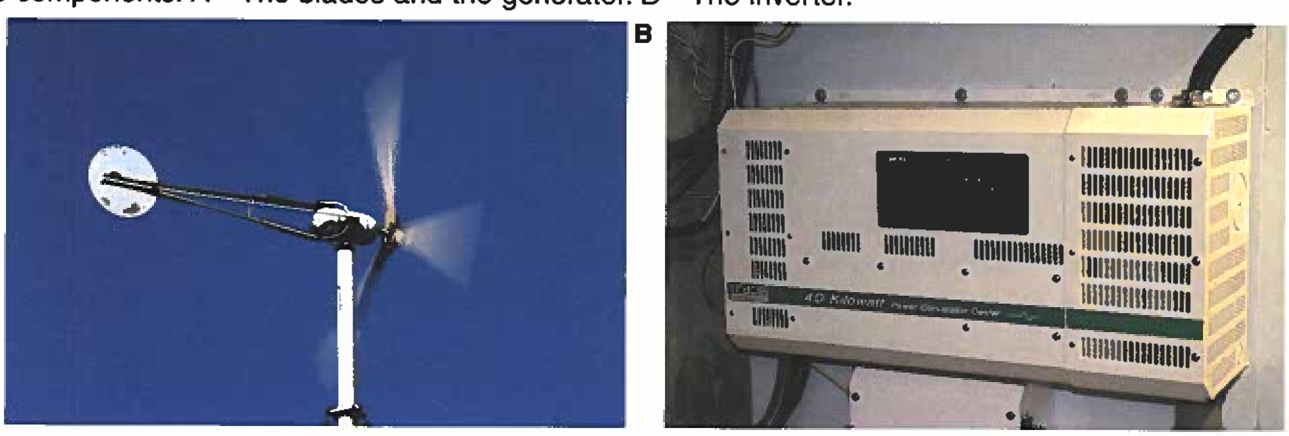
If 200 lbs. are lifted 165′ in 1 minute, how much hp is developed? To find the answer, follow these steps:

1. Determine how much work was done.
   W = D × F
   W = 165′ × 200 lbs. = 33,000 ft.-lbs.
2. Find the hp generated.
   hp = work/(time in minutes × 33,000)
   hp = 33,000/(1 × 33,000)
3. The answer is 1 hp.

Once the hp values are known, the efficiency can be determined using the following formula:

- output hp/input hp × 100 = percentage of efficiency

Figure 7-10. The total efficiency of a wind generator is calculated from the combined efficiencies of its components. A—The blades and the generator. B—The inverter.

A B


A motor consumes 2 hp and produces 1.75 hp of mechanical power. How efficient is the motor?

- 1.75 hp/2.00 hp × 100 = 87.5% efficient

Using hp as a unit of measurement allows one form of power to be compared with another form of power. To determine the efficiency of an electric motor, for example, measure the wattage used by the motor to determine the input power. With the proper instruments, measure the output rotary mechanical power produced by the motor. Because these units of power measurement are different from each other, the efficiency of the motor cannot be determined. In this scenario, using the hp unit of measurement is particularly useful. By converting both the input wattage of the motor and the output mechanical power into hp, the motor's efficiency can be calculated.

STEM Connection

Math: Canceling Units

Canceling units, or unit analysis, is based on the principles that multiplying anything by 1 does not change its value and that anything divided by itself equals 1. You know that 1 minute equals 60 seconds. Therefore, the following is true:

$$\frac{1\ \text{min}}{60\ \text{sec}} = \frac{60\ \text{sec}}{1\ \text{min}} = 1$$

The fact that the conversion ratio equals 1 no matter which units are on top is essential to the process of canceling units. If you are given a measurement in feet per second (fps), and you want to know the speed in miles per hour (mph), you will need to convert the units. For example, suppose a vehicle is moving at 80 fps, and you need to know how many mph it is going. Knowing that there are 12 inches in 1 foot, 60 seconds in 1 minute, 60 minutes in 1 hour, and 5280 feet in 1 mile, you can convert the units in the following way:

$$\frac{80\ \cancel{\text{feet}}}{1\ \cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{1\ \cancel{\text{min}}} \times \frac{60\ \cancel{\text{min}}}{1\ \text{hour}} \times \frac{1\ \text{mile}}{5280\ \cancel{\text{feet}}}$$

You can cancel units just like you cancel factors when multiplying fractions. Make sure the units cancel correctly. You are left with the units you wanted to find: miles/hour, or mph.

$$= \frac{80 \times 60 \times 60 \times 1\ \text{miles}}{1 \times 1 \times 1\ \text{hour} \times 5280} = 54.5\ \frac{\text{miles}}{\text{hour}}$$

When you encounter an energy or power calculation that requires you to convert units, just set up the problems so the units you do not need cancel out. This may take some rearranging, and you may need to find out additional conversion ratios. Once you have the problem set up correctly, you will be left with the units you need for your answer. Remember that you should be left with only one unit above the line and one unit below the line. All other units must be canceled.

While there are many formulas to convert units of power to hp, the following are the most commonly used:

- **Electrical power.**
  watts/746 = hp
- **Fluid power.**
  psi × GPM × .000583 = hp
- **Rotary mechanical power.**
  torque (ft.-lbs.) × rpm/5252 = hp
- **Linear mechanical power.**
  $\frac{550 \text{ ft.-lbs.}}{\text{sec}} = \text{hp}$ or $\frac{33{,}000 \text{ ft.-lbs.}}{\text{min}} = \text{hp}$

In using any of these formulas, the units must be exact. For example, if a formula specifies that time be measured in minutes, it must be recorded in minutes, not seconds or hours. This applies to any unit of measure included in a formula. If force is to be measured in pounds, other units, such as tons or ounces, will not result in an accurate calculation.

Measurement Conversion

It is important to know how to use measurements in power and other areas. The two measuring systems we use in the United States are U.S. customary and SI metric. It is important to know how to convert these measurements from one system to another. The chart in **Figure 7-11** provides a guide for converting many of the most common measurements used in energy, power, and transportation.

Figure 7-11. A conversion chart for U.S. customary and SI metric values.

	U.S. Customary to SI Metric					SI Metric to U.S. Customary				
	Customary Units	×	Conversion Factor	=	Metric Units	SI Metric Units	×	Conversion Factor	=	Customary Units
Length	inches	×	2.54	=	centimeters	centimeters	×	.4	=	inches
	yards	×	.9144	=	meters	meters	×	1.1	=	yards
	miles	×	1.609	=	kilometers	kilometers	×	.6	=	miles
Weight	pounds	×	.4536	=	kilograms	kilograms	×	2.2	=	pounds
Force	pounds	×	4.448	=	newtons	newtons	×	.2248	=	pounds
Torque	pound-feet	×	1.356	=	newton-meters	newton-meters	×	.7376	=	pound-feet
Pressure	pounds per sq. inch	×	6895	=	pascals	pascals	×	.000145	=	pounds per sq. inch
Work	foot-pounds	×	1.36	=	joules	joules	×	.7376	=	foot-pounds
Heat	British thermal units	×	252	=	calories	calories	×	.003968	=	British thermal units
Mechanical Power	horsepower	×	746	=	watts	watts	×	.001341	=	horsepower
Electrical Power	watts	×	1	=	watts	watts	×	1	=	watts

Summary

We often take power for granted and do not always realize it affects our everyday lives. Power is energy that has been converted to produce useful work. When energy is converted, transmitted, and controlled to do useful work, it is referred to as a power system. There are three basic types of power systems in our society: electrical systems, mechanical systems, and fluid systems. Electrical power systems range in size from toasters to manufacturing plants. Mechanical power systems convert mechanical energy into work—the energy of motion. Machines are devices that change and control mechanical power. Fluid power systems are referred to as the "muscles of industry" and may be pneumatic or hydraulic. Each type of power system contains the same basic elements, including an energy source, a conversion method, and a means of transmission, control, and storage. Electrical power is measured in watts. All forms of power can be measured in or converted to a standard unit known as horsepower (hp).

Key Words

All the following words have been used in this chapter. Do you know their meanings?

advantage-gaining device
amperage
ampere
control system
conversion method
coulomb
effort
electrical system
energy source
fluid system
foot-pound (ft.-lb.)
force
gallons per minute (GPM)
horsepower (hp)
hydraulic
load
machine
measuring device
mechanical system
pneumatic
pounds per square inch (psi)
power system
pressure
protection device
rate
revolutions per minute (rpm)
storage medium
torque
transmission path
voltage
watt
Watt's law
work

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. What is the difference between work and power?
2. Define power.
3. Name the three basic types of power systems.
4. Summarize how different forms of power are used for specific applications.

5. Give examples of three components of an electrical circuit and three components of a fluid circuit.
6. Name the two types of fluid power.
7. Discuss briefly the advantages and disadvantages of different forms of power.
8. The term for the rate characteristic of electricity is known as _____.

Matching questions: For Questions 9 through 17, match the examples on the left with the correct term on the right.

9. _____ Fuel, water, and wind.
10. _____ Falling water that spins a turbine to produce electricity.
11. _____ Electrical power lines.
12. _____ Batteries and springs.
13. _____ Fuses.
14. _____ Levers, transformers, and transmissions.
15. _____ Throttles.
16. _____ Meters, indicators, and gauges.
17. _____ Cutting blades, motors, and televisions.

A. Advantage-gaining devices.
B. Control systems.
C. Conversion methods.
D. Energy sources.
E. Loads.
F. Measuring devices.
G. Protection devices.
H. Storage media.
I. Transmission paths.

18. Electrical power is measured in _____.
19. Explain the concept of efficiency.
20. The efficiency of a component is calculated by dividing the power output by the _____.
21. A machine has a motor that draws 9.7 amps at 120 volts. The machine can produce the mechanical equivalent of 900 watts of power. How efficient is the machine?
22. Calculate the efficiency of a hydraulic motor, given the following characteristics:
    - input effort: 100 psi
    - input rate: 75 GPM
    - output effort: 12.5 ft.-lbs.
    - output rate: 1200 rpm
23. A power system is comprised of four components. The efficiency for each component is as follows: 90%, 93%, 67%, and 85%. What is the total efficiency for the power system?
24. What is the formula for determining work?
25. A person moves 350 lbs. of roofing shingles 100′. How much work has been performed?
26. A standard unit of measurement for all forms of power is known as _____.

27. If the work in the Problem 25 is accomplished in 25 minutes, what is the average hp utilized?
28. Motors are rated in terms of their horsepower (hp) output. In order to calculate the efficiency, the power input and output of a motor must be in the same unit of power measurement. An electric motor on a lift is rated at 8 hp. The electrical current required by the motor is 28 amps at 240 volts. What is the efficiency of the motor?
29. A compressor motor provides 10 hp to a pump. If the motor is 85% efficient, what is the power input to the motor?
30. A lift can move 3000 lbs. a distance of 8′ in 10 seconds. How much hp is delivered to the lift, if the lift is 90% efficient?
31. An alternator in a car produces 40 amps at 12 volts. How much power is being produced? How much hp is being produced?
32. A hydraulic pump produces a pressure of 300 pounds per square inch (psi) and a flow rate of 75 gallons per minute (GPM). What hp is the pump producing?

STEM Activities

1. Design a machine that uses multiple forms of power. The machine should serve a practical purpose and include each of the basic elements of power systems discussed in the chapter. Include a sketch of your machine and a sample workflow.
2. Calculate the kilowatt-hour (kWh) consumption of your home for one month. Note the number of people living in your home and the square footage of the home. Be prepared to share your findings in class.

Career Skills

Work Habits

Employers want employees who are punctual, dependable, and responsible. They want their employees to be capable of taking initiative and working independently. Other desirable employee qualities include organization, accuracy, and efficiency.

A punctual employee is always prompt and on time. This means not only when the workday starts, but also when returning from breaks and lunches. Being dependable means that people can rely on you to fulfill your word and meet your deadlines. If you are not well, be sure to call in and let the employer know right away. If there are reasons you cannot be at work, discuss this with your employer and work out an alternate arrangement.

Taking initiative means that you start activities on your own without being told. When you finish one task, you do not wait to hear what to do next. Individuals who take initiative need much less supervision. They have self-motivation, or an inner urge to perform well. Generally, this motivation will drive you to set goals and accomplish them. All these qualities together show that you are capable of working independently.

You are expected to be as accurate and error-free as possible in all that you do. This is why you were hired. Complete your work with precision and double-check it to ensure accuracy. Your coworkers depend on the careful completion of your tasks.

A good employee knows how to manage time wisely. This includes ability to prioritize assignments and complete them in a timely fashion. It also involves not wasting time. Time-wasting behaviors include visiting with coworkers, making personal phone calls, texting, sending e-mails, or doing other nonwork activities during work hours.

While it is important to complete all your work thoroughly, you must also be able to gauge which assignments are most important. Avoid putting excessive efforts into minor assignments when crucial matters require your attention. Even though you are still accomplishing work, this is another way of wasting of time.